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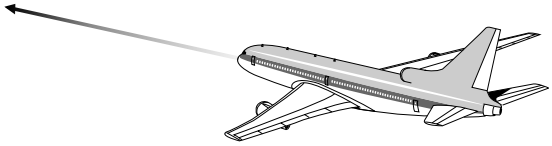
FS 1998-04-042-DFRC

ACLAIM

Airborne Coherent LIDAR for Advanced In-Flight Measurement



Project Summary

The Airborne Coherent LIDAR for Advanced In-flight Measurement (ACLAIM) project at NASA's Dryden Flight Research Center is a multi-year research project to develop and validate a sophisticated laser-based system to detect and give aircraft flight crews advance warning of clear air turbulence ahead.

The project is part of NASA's Aviation Safety Program, a partnership including the Federal Aviation Administration (FAA), the aviation industry and the Department of Defense. Its goal is to develop technology and training to reduce the fatal aircraft accident rate by 80 percent within 10 years and by 90 percent within 20 years. Reduction of the aircraft accident rate is one of the primary goals of the Global Civil Aviation pillar of NASA's Aeronautics and Space Transportation Technology Enterprise.

Part of the Aviation Safety initiative involves comprehensive turbulence research. On average 17 U.S.-based planes experience turbulence severe enough to cause injuries each year. Since FAA statistics show that 98 percent of those injuries are sustained by people not wearing seat belts, an alert of impending turbulence would give the flight crew time to warn passengers and attendants to buckle up or to take other defensive measures. The alert also could allow the pilot to change the autopilot control mode to help the aircraft ride out the turbulence more smoothly.

In addition, a long-term goal is to develop an interface to couple the detection system into the flight control computers. This interface would allow the effects of turbulence on the aircraft and passengers to be partially alleviated by automatic counteracting movements of the aircraft's control surfaces.

Clear Air Turbulence

Atmospheric turbulence is the leading cause of in-flight injuries experienced by the flying public, and can result in death in extreme situations.

Turbulence is often associated with visible storm systems. In these situations, the turbulent conditions can be observed by radar and the aircraft can avoid the dangerous region. Not so with clear-air turbulence, a condition occurring at cruise altitudes that has few if any visible warning signs for even the most conscientious pilots.

Clear air turbulence is often found on the outskirts of thunderstorms, up to 50 miles away from the actual storm activity. It also occurs near the boundaries of high altitude air currents called jet streams and in the vicinity of mountain ranges and surface weather fronts. There are currently no effective systems to warn flight crews that they are approaching clear air turbulence. One of the only ways that commercial or other aircraft can avoid encounters is to heed recent pilot reports of turbulence and if possible, avoid the hazardous region of the atmosphere.

Additional work in the turbulence research program is under way to improve understanding of the clear air turbulence phenomena and thereby improve the quality of turbulence forecasting.

ACLAIM Project Background

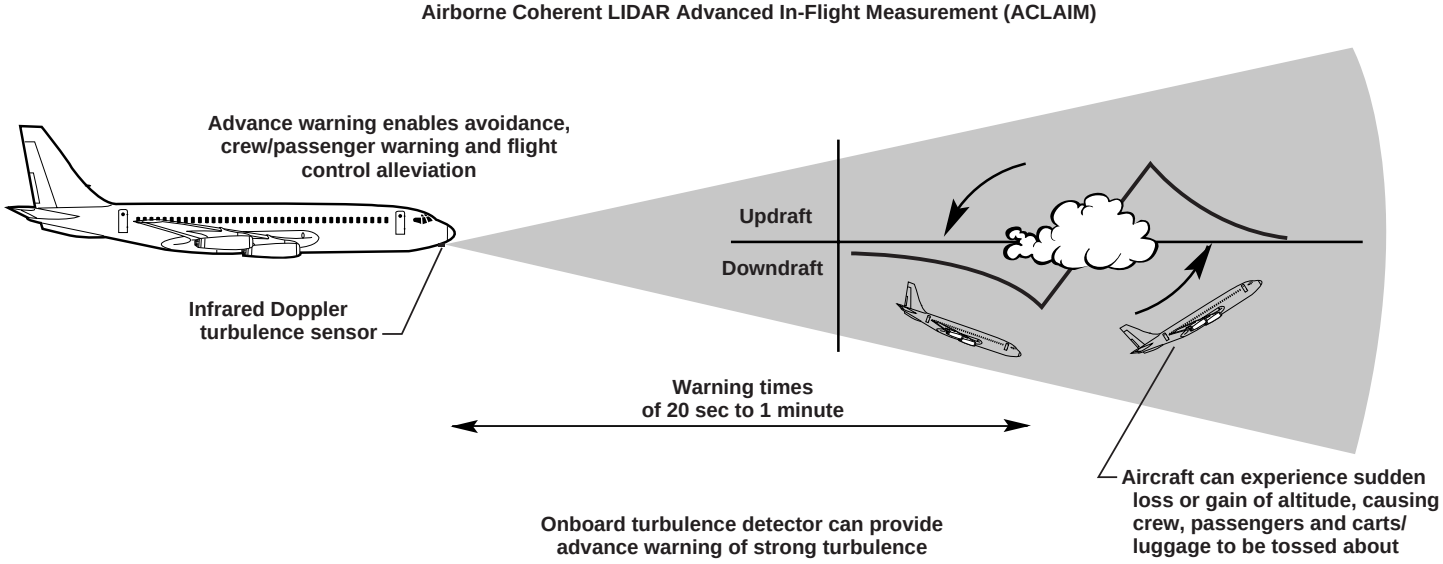
The ACLAIM project was begun several years ago to develop a way to detect oncoming turbulence in order to avoid detrimental effects to the supersonic propulsion system of the planned High Speed Civil Transport. The NASA Aviation Safety Program recognized that the same technology could be used to provide turbulence alerts to subsonic aircraft. The safety program absorbed ACLAIM and re-directed its research to subsonic aircraft. Financial support has been received for fiscal years 1998 and 1999.

The primary task of ACLAIM is to develop a flight-qualified remote turbulence sensor system using solid-state laser technology. This sensor system is being produced by Coherent Technologies, Inc., Lafayette, Colo. The program is scheduled to begin flight research missions in Spring 1998. The program also includes research in a number of other areas, all of which are aimed at providing greater insight into the feasibility of using such systems, based on the LIDAR concept, as on-board turbulence alert sensors.

LIDAR Sensor System Function

"LIDAR" is an acronym derived from LIght Detection And Ranging, a concept similar to the that used in the more familiar “radar” acronym, which stands for Radio Detection And Ranging. The LIDAR principle relies on the presence of natural airborne particles that move with atmospheric winds. These particles, or “aerosols,” are extremely small and always present. High aerosol concentrations are visible as haze, while during clear, high-visibility conditions they are invisible to the human eye.

Coherent Technologies Inc. has designed and fabricated a self-contained, flight-rated LIDAR turbulence sensor that includes its own data reduction and recording capability. The device transmits a laser light pulse of two microns wavelength at a rate of 100 per second, and the aerosols reflect some of the light back into a sensor. The light received by the sensor is shifted in frequency (called a Doppler shift) as a result of the aircraft motion relative to the aerosols.



The two-micron wavelength (in the near-infrared region of the electromagnetic spectrum) gives increased aerosol reflection than the longer wavelengths used in prior experimental systems provided, thus improving the sensitivity of the system. In addition, the human eye effectively absorbs much of the energy at the two-micron wavelength, thus preventing eye retina damage from all but very high pulse energy levels.

The wind velocity at selected points along the laser beam path may be determined by analyzing the frequency of the reflected light. As long as this velocity is uniform, no turbulence exists. Highly variable velocity, however, indicates the presence of turbulence. The range at which turbulence can be detected depends on the aerosol concentration and the energy of the light pulse. The ACLAIM system is expected to detect turbulence at a distance of at least one mile and possibly as many as ten or more miles in front of the aircraft.

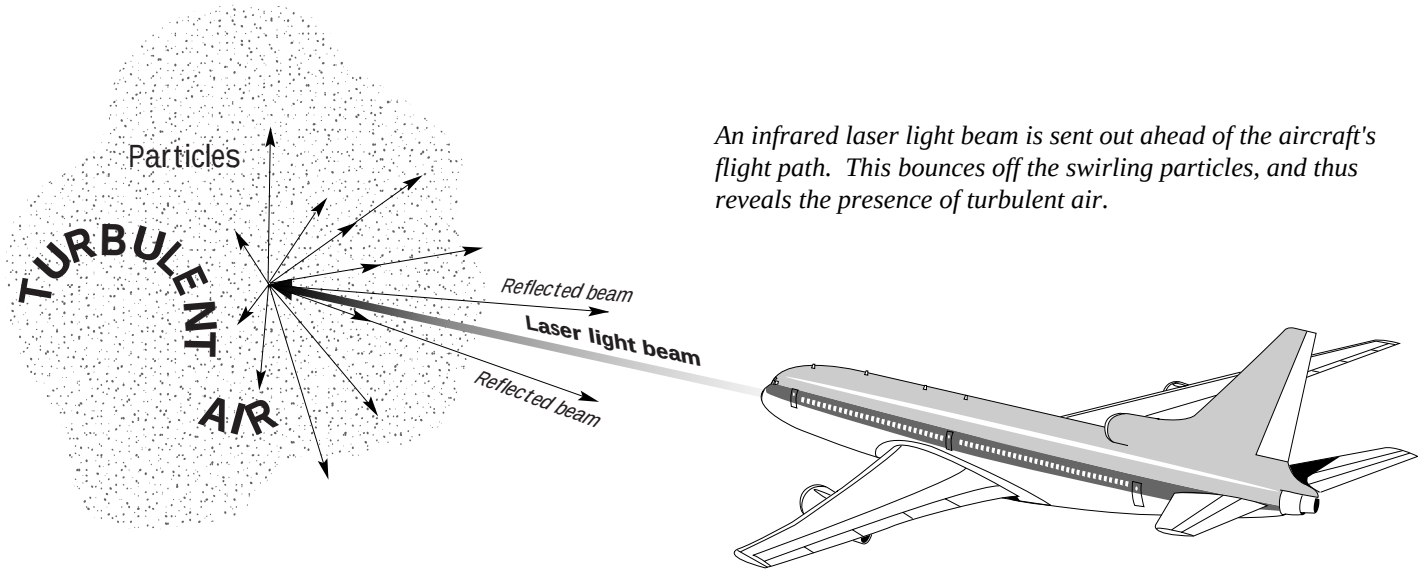
Flight Research

Flight tests are critical in the development activity to validate results in a real environment and to reduce risk for subsequent phases of the program. The first set of flights will be conducted to validate the performance of the prototype LIDAR sensor.

The initial series of tests will occur aboard a Lockheed L-188 Electra; a modified four-engine turboprop airliner that is operated by the National Center for Atmospheric Research (NCAR) as a flying laboratory. The validation tests will involve several flights totaling about 10 hours of flight time and will include atmospheric aerosol measurements to help confirm data received by the sensor system.

Turbulent conditions will be located and the turbulence will be measured by the LIDAR sensor prior to encounter by the aircraft. The pre-encounter laser-measured turbulence will be compared to the effects of that same turbulence on the aircraft at encounter. In this way, the correlation can be established between the LIDAR-measured turbulence characteristics and the actual turbulence experienced by the aircraft. These tests will provide an efficient checkout of the flight hardware and begin to characterize turbulence measurements.

Follow-on flight tests will use testbed aircraft representative of those in current commercial service to gain experience in different environments. Possible testbed aircraft include the NASA Airborne Science Program DC-8 based at Dryden and a Boeing 757 based at NASA's Langley Research Center, Hampton, Va.



An infrared laser light beam is sent out ahead of the aircraft's flight path. This bounces off the swirling particles, and thus reveals the presence of turbulent air.

Project Partners

NASA Dryden Flight Research Center, Edwards, Calif.: Responsible for overall project management and flight testing. Rodney K. Bogue is project manager of ACLAIM. During the past several years, NASA Dryden has successfully flight tested several advanced laser-based sensors. The experience gained in these programs along with the flight research infrastructure at Dryden gives the Center unique capability for flight testing state-of-the-art laser-based sensors.

Coherent Technologies, Inc. , Lafayette, Colo.: Responsible for design and development of the prototype lidar sensor equipment and integration onto the test aircraft. Coherent Technologies is a small company dedicated exclusively to LIDAR technology development and commercialization.

National Center for Atmospheric Research, Boulder, Colo.: Provided the Lockheed L-188 Electra laboratory aircraft as a testbed for the initial flight tests of the ACLAIM turbulence detection system. The experience of the NCAR organization provided crucial assistance in understanding and interpreting the data obtained during initial flight testing.

NASA Marshall Space Flight Center, Huntsville, Ala.: Providing program management support. NASA Marshall has played a pioneering role in the development of pulsed coherent Doppler LIDAR sensors for atmospheric velocity measurements, concentrating on low-backscatter conditions, which are directly applicable to this program.

Global Hydrology and Climatology Center, Huntsville, Ala.: Responsible for providing data on the distribution of atmospheric aerosol particles around the world to assist researchers in establishing requirements for turbulence sensor systems.

NASA Langley Research Center, Hampton, Va.: NASA Langley researchers have unique experience building and fielding laser sensors for atmospheric measurements. Langley personnel are providing technical assistance and direction, focusing on atmospheric science in the areas of stratospheric aerosol characteristics and LIDAR turbulence measurement.

Boeing Commercial Airplane Group, Seattle, Wash.: Responsible for developing an interface to incorporate the turbulence measurements from the LIDAR detection system into aircraft flight control computer software to help alleviate the effects of turbulence.

Technology Commercialization

The primary thrust of the ACLAIM clear air turbulence detection project is to reduce risk of injury to the traveling public and the attendant liability to the airline industry. In addition to the safety-related benefits, the same technology is capable of acquiring additional information that will benefit airlines, passengers and the aircraft industry.

When equipped with a movable scanning system, the LIDAR detection system will be able to measure wind speeds above and below the aircraft cruise altitude. The flight crew can use that information to help them decide whether to change altitude to obtain more favorable wind direction for improved cruise fuel economy and ride quality.

Since the LIDAR measures wind speed very accurately at cruise altitudes, aircraft manufacturers can use the system to calibrate the conventional airspeed systems on commercial aircraft. One manufacturer has reported substantial economic benefits by use of a similar system to support calibration of airspeed systems on its series of aircraft.

April 1998